Background Information for Engineering Brief #65, *Minimum Requirements to Widen Existing 150-Foot-Wide Runways for Airbus A380 Operations*

With the pending arrival of the Airbus A380 aircraft, many airports are searching for ways to accommodate this new aircraft with their existing facilities. One of the first issues that must be addressed by many airports is the strength and width of the runway and taxiway pavements. Existing Group V airports are required to have runway widths of 150 feet (45m) with 35-foot (10.5m) shoulders. The A380 is a Group VI aircraft that requires a 200-foot-wide (60m) runway with 40-foot (12m) shoulders.

Several large Group V airports in the United States are expecting limited operations of the A380 for several years and are having difficulty justifying reconstruction costs to provide full-width runways and shoulders. To minimize construction cost and airport delays, airport operators have asked for relief in the form of reduced pavement requirements for the outer 25 feet (7.5m) of the runways. If existing shoulder pavements can be utilized as runway pavement with little or no modification, then existing runways can be widened by merely relocating edge lights, re-marking, and adding new shoulder pavements. A problem arises, however, in that shoulder pavements are constructed for occasional passage of an aircraft and do not meet the strength requirements for runway pavements.

To address this issue, full-scale pavement testing at the FAA National Airport Pavement Test Facility (NAPTF) in Atlantic City, NJ, was conducted to determine how under-designed pavement sections would perform with infrequent aircraft operations. The construction cycle three (CC3) test pavement contained four different pavement cross-sections. The thickness of the structural layers of the four test pavements is shown in Figure 1.

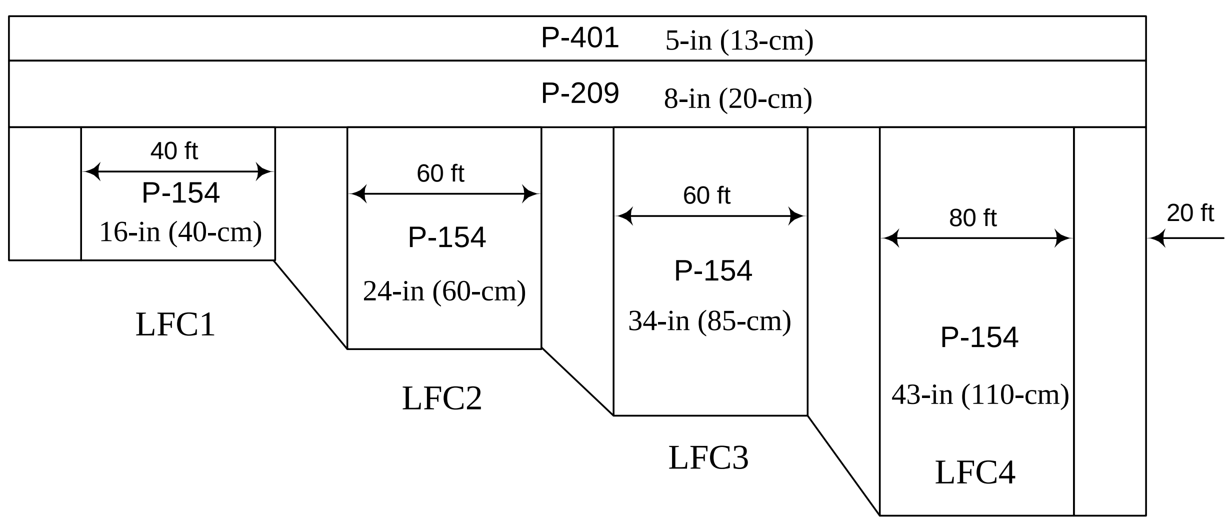

Figure 1. Construction Cycle Three (CC3) Pavement Cross-Sections

The sections shown in Figure 1 were originally based on subgrade CBR=3 and were designed to fail after various levels of repetitions by a simulated aircraft gear with 55,000-pound wheel loads. A dual tandem gear and a triple dual tandem gear, which are both present on the A380, were used for the test. The test sections of particular interest for this analysis are the LFC1 and LFC2 sections. Table 1 shows the repetitions or passes of the test gear to failure for LFC1 and LFC2 for each gear configuration.

	Repetitions to Subgrade Failure	
	4-Wheel Gear	6-Wheel Gear
LFC1	132	90
LFC2	2970	1584

Table 1. Repetitions to Subgrade Failure for LFC1 and LFC2 Test Sections

Observation of the pavement sections during full-scale testing indicated that the LFC1 section was very weak and exhibited considerable surface deformation with each pass of the test gear. Vertical deformation of 2 to 3 inches was observed during the first few passes. In addition to vertical deformation, the pavement was very soft and rolled (like a wave) ahead of the test wheels. This degree of movement would not be acceptable on an airfield runway, regardless of location or frequency of aircraft operations.

The LFC2 section was considerably stronger than the LFC1 section and exhibited only minor surface deformation with each repetition of the test gear. Although both sections experienced surface rutting with minimal repetitions (see Table 2), the LFC2 section proved more than adequate for limited aircraft operations. A pavement section somewhere between LFC1 and LFC2 would be acceptable for minimal runway operations such as that expected on the outer 25 feet of a 200-foot runway. This acceptance must be made with the understanding that permanent surface deformation may occur with each repetition of an aircraft. In addition, an airport operator must be prepared for inspection and repair as necessary with each repetition on the reduced-strength pavement.

It is also important to note that the pavement failure as defined for the NAPTF test would not be acceptable for normal airfield operations. Vertical pavement deformation and surface deterioration would reach unacceptable levels before complete pavement failure as defined by NAPTF would be achieved. From Table 2, it can be seen that vertical deformations (rutting) several inches in depth were observed early in the test cycle. For active airfield applications, these areas would require remedial action when only minor surface deformation had occurred.

	Surface Rut Depth (inches)			
Repetitions	LFC1 6-Wheel	LFC1 4-Wheel	LFC2 6-Wheel	LFC2 4-Wheel
1	0.32	0.45		
24	1.34	1.54	0.92	0.88
48	2.64	2.09	1.51	1.45
66	3.81	2.89	1.69	1.82
90	3.99	3.24	2.08	2.02
114	X	3.55	2.27	2.22
132		4.02	2.38	2.44
198		X	2.95	2.87
264			3.39	3.27
330			3.91	3.54
396			3.96	3.78
462			4.00	4.18
528			4.46	4.23
594			4.75	4.33
660			5.06	4.59
726			5.24	4.63
858			5.66	4.95
990			6.09	5.24
1188			6.63	5.55
1386			7.15	5.81
1452			7.37	X
1584			X	6.07
1650				6.17
1914				6.45
2112				6.68
2244				6.77
2376				6.87

Table 2. Surface Rutting with Load Repetitions

The LFC1 and LFC2 test sections were analyzed using LEFAA Version 1.3 software to determine what activity of the A380 aircraft would demand the same pavement sections. Before analyzing the pavement sections for the A380, the sections were validated using the gear geometries actually used during the full-scale testing. The pavement sections were characterized as follows:

Surface	5" ACC surface	E = 200,000 psi (indoor conditions, surface temps <= 80 degrees)
Base	8" P209 layer	E ~ 60,000 psi (variable)
Subbase	P154 layer	E = 37,500 psi CBR= 29 (used undefined layer since actual material was stronger than normal P154 material)
Subgrade	Select Clay	CBR = 4.0 E = 6,000 psi (average of values of NAPTF sections) (CBRs were variable with depth)

Before proceeding with a detailed analysis of the pavement sections, it is appropriate to discuss how the Pass-to-Coverage (P/C) ratio determined for flexible pavement sections in the LEDFAA program is different from the ratio discussed in AC 150/5320-6D, *Airport Pavement Design and Evaluation*. LEDFAA computes the ratio at the top of the subgrade layer, whereas the procedure in AC 150/5320-6D calculates the ratio at the pavement surface. The ratio calculated at the top of the subgrade is influenced by wheel spacing and the resulting load distribution. In general, the value determined in LEDFAA will be smaller than the value calculated with AC 150/5320-6D, i.e. more coverages per pass.

LEDFAA produced the LFC2 section using 909 total annual departures of the dual tandem gear configuration with 55,000-pound wheel loads. The P/C ratio, which is dependent upon the pavement thickness, was 0.59, which equates to 909/0.59 = 1540 coverages. The LFC2 section failed after 2970 passes or 5033 coverages of the four-wheel test apparatus, which is reasonably accurate given the conservative nature of LEDFAA. This suggests the layer properties are appropriately modeled. Also, it must be remembered that full failure of the NAPTF sections represented pavement damage that would not be acceptable for active airfields.

LEDFAA produced the LFC1 section using 111 total annual departures of the dual tandem gear configuration. The P/C ratio was 0.67, which equates to 165 coverages. The LFC1 section failed after 132 passes or 197 coverages of the four-wheel test apparatus. Observations of the LFC1 section during testing showed it was very spongy and had considerable surface defection (2 to 3 inches) with each wheel pass. Surface depressions of this magnitude would cause control problems with an aircraft trying to correct steering at operational speeds. Based on the initial observations of the LFC1 section, the FAA would not recommend it for outer perimeter pavement of a runway, even though the pavement could withstand a limited number of passes. Additional testing of the LFC1 sections approximately 1 year after construction indicated that the section stiffened due to small increases in subgrade CBR and/or hardening of the surface asphalt. Surface deformations decreased to more acceptable levels.

The LFC2 section was considerably stronger, with only minor surface deflections during traffic. The defections observed during testing of LFC2 would not pose a concern for aircraft operations.

Keeping the layer properties discussed above, the dual tandem gear was replaced with the A380 aircraft as defined and addressed in the LEDFAA program. LEDFAA assumes that interaction from all main gears is present and must be accounted for in the pavement design. The general influence of this assumption is to increase the total required pavement thickness over that of an individual gear analysis. The maximum weight was set at 1.3 million pounds, which generates individual wheel loads of 61,750 pounds. Results are as follows:

Section	Surface	Base	Subbase	Allowable coverages
LFC1	5"	8"	16.0"	87
EB65	5"	8"	19.72"	241
LFC2	5"	8"	24"	622

A conservative goal of supporting two passes of the A380 over the reduced runway pavement per month equates to approximately four coverages per month due to the low P/C ratios. Multiplying years by annual coverages results in a total of 240 coverages for a 5-year design period. A 5-year period was selected because Engineering Brief #65 (EB65) was intended to serve for a limited time (up to 5 years) until full-strength pavement sections could be constructed. To support this level of traffic, 3.7 inches of additional subbase material must be added to the LFC1 section. This places the pavement section required by EB65 between the LFC1 and LFC2 sections.

Comparison to Airbus Shoulder Study

Airbus performed limited full-scale testing to consider a similar issue of shoulder pavement design. Their intent was to provide minimal acceptable pavement sections that would support occasional A380 loads. One of the sections that was considered acceptable by the Airbus study was analyzed using the LEDFAA program. The Type 1 section consisted of 2.4 inches of asphalt surfacing, 8.0 inches of asphalt macadam, and 30 inches of improved clay material with a CBR of 6.0 over a subgrade CBR of 3.0. The section was tested by pulling a simulated gear, loaded to a gross aircraft weight of 1.239 million pounds, across a test section.

Using only the A380 wing gear (1,239,000 pounds total aircraft weight) for analysis, the coverages to failure from LEDFAA would be 52 total departures or 52/0.54 = 96 coverages. This appears reasonable based on the NAPTF test sections. The Airbus study did not discuss surface deflection or pavement movement, but did discuss sinking of the gear on the slightly lighter pavements. This suggests that the Airbus sections are indeed marginal and only serve to allow limited passages of the aircraft. Lack of discussion regarding surface deformations prevents speculation on directional control issues.

Performing the same analysis of the Airbus sections using the full A380 geometry resulted in 38 total departures or 38/0.36 = 105 coverages. Again this seems reasonable as the pavement sections appear marginal and only serve to allow limited passages of the aircraft. (Note the significant difference in the P/C ratio between the aircraft and the wing gear analysis.)

To increase the strength of the Airbus sections to meet EB65 requirements, the ACC base layer must be increased by 3.3 inches for the full A380 geometry and by 2.6 inches for the A380 wing gear. The full A380 geometry should be used to account for the proximity of other gears on the aircraft and to help account for non-uniform loading, which may occur during an excursion of the aircraft to the outer perimeters of the runway pavement.

Comparison with JFK Pavements

The John F. Kennedy International Airport, operated by the Port Authority of New York and New Jersey (PANYNJ), expects limited operations of the A380 aircraft as early as 2006. Runway pavements at the airport are sufficient; however, the taxiway pavements and shoulders had to be addressed. Although the EB65 guidance is specific to runways, it is also suitable for determining whether a pavement can accept limited operations of the A380. Existing taxiway shoulder pavements at JFK are constructed of—

4" Asphalt Concrete Top Course (2" E = 200,000 psi, 2" E = 400,000 psi)
6" Plant Mix Macadam (E= 150,000 psi)

8" Aggregate Base Course (E determined by LEDFAA)
Subgrade Soil – E = 15,000 psi

The JFK example can be analyzed by entering the existing pavement section into LEDFAA along with the A380 aircraft and then selecting the "calculate life" feature of the program. For initial design purposes, the analysis assumed the gross operating weight of the A380 as 1,300,000 pounds. The resulting total departures were calculated and could be viewed by reviewing the aircraft data. LEDFAA determined that a total of 131 total departures (215 coverages P/C = 0.61) could be supported by the existing shoulders. Therefore, the existing shoulder pavement would need to be strengthened to meet the EB65 requirements.

Comparison with Memphis-Shelby County Airport

The Memphis-Shelby County Airport is home to a large Federal Express cargo operation, which expects to operate the A380. The airport is currently a Group V airport with 150-foot-wide runway pavement and 35-foot-wide runway shoulders. The runway pavement consists of 19 inches of PCC pavement on a 4-inch porous bituminous layer on an 8-inch cement-treated aggregate layer on a 6-inch soil-cement subbase course. In comparison, the runway shoulders consist of 4 inches of ACC over a variable thickness crushed stone base course. The base course ranges in thickness from 15 inches next to the runway edge to 8 inches at the outer perimeter of the shoulder. As a temporary accommodation for the A380, the airport has considered the feasibility of using the existing runway shoulders as runway pavement by moving the edge lights out and re-striping the runway width.

The airport authority performed non-destructive testing to establish layer properties and to confirm the overall support provided by the shoulder pavements. Back-calculated subgrade support ranged from 12 to 20 CBR, with an average near 18. The high CBR values are most likely due to treatment of the subgrade materials during original construction.

For the purpose of this analysis, a worse case scenario would occur where the thinnest subbase thickness is provided, i.e. 25 feet from the runway edge. The resulting pavement section is 4 inches of asphalt over 10 inches of subbase material. From LEDFAA, 118 coverages of a 1.3 million-pound A380 are allowed. The design is sensitive to the subbase thickness and will vary depending on the subbase thickness. To address this issue, the thickness of the subbase was averaged over the first 25 feet from the runway to establish a subbase thickness of 12.5 inches. For this scenario, LEDFAA allowed 832 coverages of the A380.

In the Memphis case, the pavement layers are considerably thinner than would be considered acceptable, and had it not been for the high subgrade CBR values, the pavement would not have provided sufficient support for the A380. To stress this point, LEDFAA calculations were performed on the average pavement section while varying the subgrade support. Results are shown in Figure 2. From Figure 2, it can be seen that small changes in the subgrade support value cause large changes in the allowable coverages. This is especially true for CBR values greater than 13.

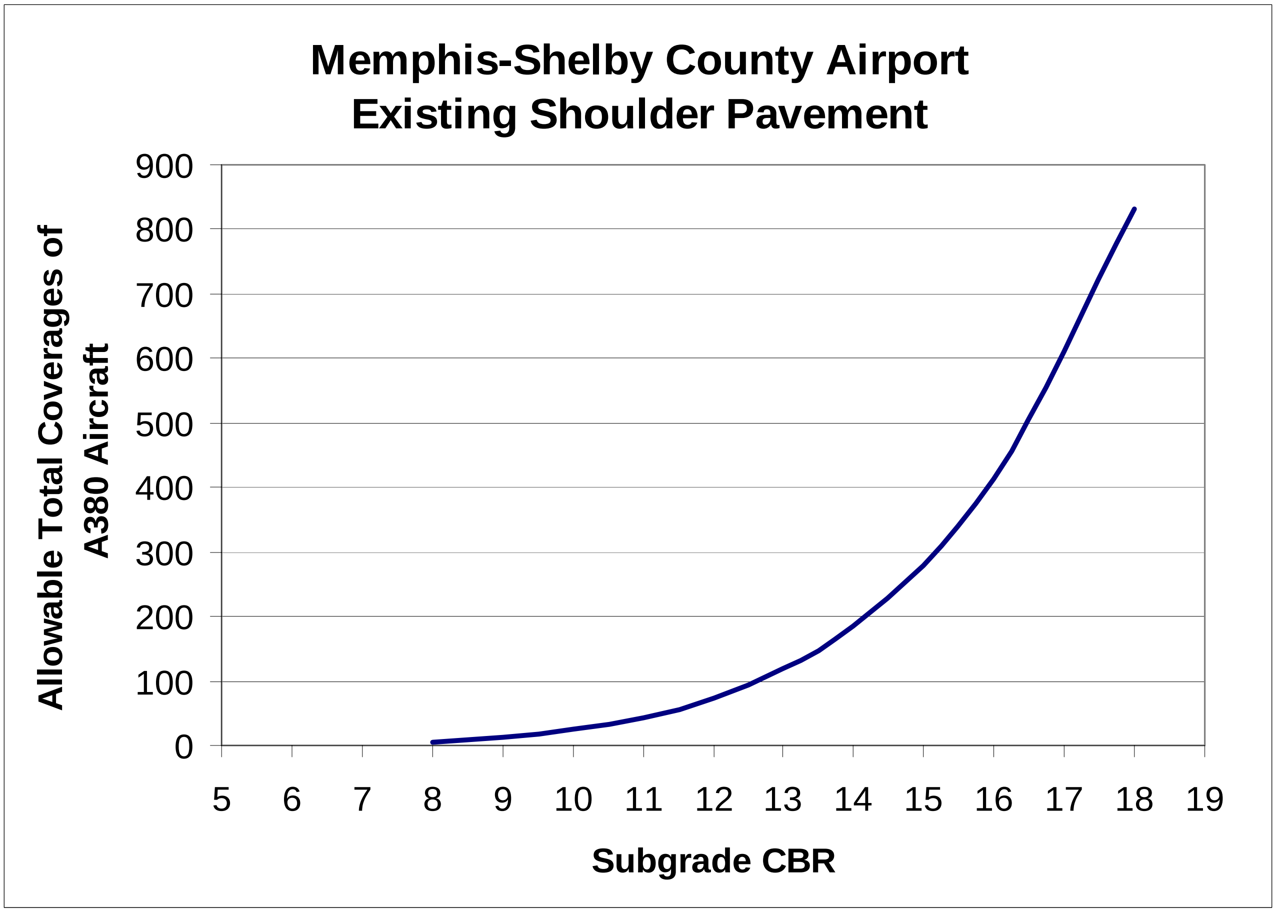

Figure 2. Memphis-Shelby County Airport, Allowable Coverages versus Subgrade Support

As a second means of comparing the pavement sections, the runway shoulder was converted to a similar section as that constructed at the NAPTF. An equivalency factor from Table 3-6 of AC 150/5320-6D was used to make the layer conversion. The equivalent section would be comprised of 4 inches of ACC and 8 inches of P-209 aggregate base course and the remainder converted to P-154 subbase material. The P-209 material was converted to equivalent subbase by a generous factor of 1.8. The conversion and material equivalency factors are shown in Figure 3.

When the equivalent thickness section of Figure 3 is analyzed in LEDFAA, 312 coverages are allowed at a CBR of 18. In either case, as long as the subgrade CBR is near 18, the existing shoulder pavement is sufficient to meet the requirements of EB65, with the exception of the required asphalt thickness of 5.0 inches.

In the Memphis case, it would be prudent to confirm the subgrade support and to consider seasonal effects on the subgrade. It is critical that the subgrade support be present for the shoulder pavement to perform as desired. Significant surface deformation and remedial maintenance should be expected with single aircraft operations.

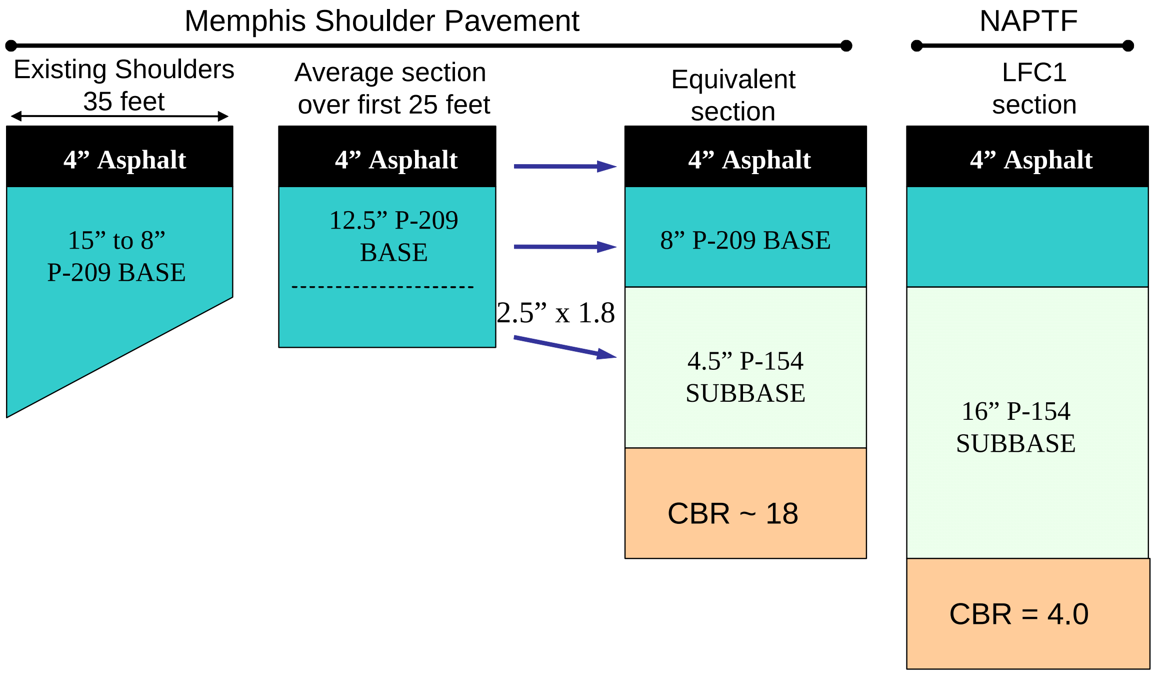

Figure 3. Memphis Shoulder Pavement Conversion to Equivalent Pavement

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